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AGE DETERMINATION OF FISH
(Preliminary Report 1)

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Explanatory Note

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AGE DETERMINATION OF FISH (PRELIMINARY REPORT 1)

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Pacific Oceanic Fishery Investigations

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1/ Fisheries Experiment Station. From Bulletin of the Japanese Society of Scientific Fisheries, Vol. 7, No. 1, pp. 79-88. May 1938.

Synopsis [in English]

On the basis of rings formed on the surface of centrum of vertebrae, ages of tunny, yellow-finned tunny, long-finned albacore, and bonito were determined as follows.

(1) Tunny - Thunnus orientalis (T. & S.): L_n(cm)=7.94 r_n(mm) - 4.8, where r_1=4.1, r_2=6.4, r_3=9.4, r_4=12.6, r_5=15.8, r_6=19.4, r_7=22.4, r_8=25.4, and r_9=28.0.

(2) Yellow-finned tunny - Neothunnus macropterus (T. & S.): L_n=8.4 r_n - 8.4, where r_1=5.6, r_2=7.6, r_3=9.4, r_4=11.4, and r_5=13.6.

(3) Long-finned albacore - Germo germo (Lacépède): L_n=5.8 r_n 17±5, where r_1=3.2, r_2=4.9, r_3=6.4, r_4=7.9, r_5=9.4, r_6=11.0, r_7=12.7, and r_8=14.2.

(4) Bonito - Katsuwonus vagans (Lesson): L_n=6.15 r_n+5.5, where r_1=3.2, r_2=4.5, r_3=5.8, r_4=7.2, r_5=8.5, and r_6=9.6.

L_n is the body length in cm of the n-aged fish, when the n-th of the radius r_n mm was completed.

[Translation begins]

The age of fish was determined by using the vertebrae, just as was done in the case of the bonito(1) and chub mackerel(2). There are many examples of the use of this method to determine the age of fishes, not only in Japan but in various foreign countries as well. With this method, just as when using scales and otoliths, various sorts of critical tests are necessary. The author made determinations of the ages of various species on a broad scale as a preliminary study, and tried to corroborate his tentative results by a consideration of the character of the length and weight groups in the catch. The author hopes to establish this method on a firm basis by testing his results with a further accumulation of data and by a study of the way in which the annual rings are formed in the vertebrae. Deep thanks are offered to Mr. Kinosuke Kimura, who supplied various criticisms and valuable morphometric data for this paper.

I. Black Tuna Thunnus orientalis (Temminck & Schlegel)

Eight small black tuna (Izu Ajiro Fish Market, Table 1) and four large black tuna (Tōkyō Market) caught on hook and line were obtained and an attempt was made to determine their ages by means of the vertebrae. Five vertebrae from No. 7 to No. 12 were used. The vertebrae were split longitudinally and the total radius of the centrum from the center of the vertebrae to its outer edge (T mm) and the radius of each ring (r mm) were measured. (Table 2). The correlation between these figures and the body length (L cm) was examined. (Figure 1).

Just as in the bonito, the development of the vertebrae is accompanied by an increase in body length. The relationship can be shown by $L_1/L_2 = (r_1-0.48)/(T_2 - 0.48)$. From the radius of n ring (r_n mm) the body length at which the ring was completed can be found by the following formula.

$$L_n=7.94\ r_n-4.8$$

(1) Aikawa, Hiroaki; Bull. Jap. Soc. Scientific Fisheries 6(1), 1937.
(2) Aikawa, H.; Bull. Jap Soc. Scientific Fisheries 6(1), 1937. [in English]

Table 1 Morphometric Data on Small Black Tuna

Serial No.	1	2	3	4	5	6	7	8
Total length	39.4	43.0	43.3	43.9	47.9	50.9	49.7	56.7
Body length	34.0	37.3	37.6	38.5	40.0	43.9	43.0	48.2
Head length	10.6	11.2	11.2	11.5	12.4	13.6	13.0	15.5
Dorsal spines	XIII-15	XIV-15	XIV-15	XIII-15	XIV-15	XIV-15	XIV-14	XIII-15
Anal rays	15	14	15	15	14	14	14	14
Finlets	9/8	8/7	7/7	8/8	8/7	8/8	8/8	8/7
Vertebral count	39	39	39	39	39	40	40	40
Weight gr	920	1191	1220	1458	1458	2370	2270	3170
Condition factor	23.4	23.0	23.5	25.5	22.8	28.0	28.6	28.3

Fish taken off Ajiro in Izu, 12-17-37.

Consequently ring No. 1 (r_1) was completed at body length (L_1) 43 cm, ring No. 2 (r_2) at 69 cm, ring No. 3 (r_3) at 93 cm, r_4 at 118 cm, r_5 at 143 cm, and r_6 at 168 cm. Furthermore, if the body length increases at the same rate, it is assumed that r_7 will be completed at 190 cm, r_8 at 210 cm, r_9 at 230 cm, and r_{10} at 250 cm.

The average condition factor for black tuna is 27.8 for fish of the year, 26.5 for fish in their 2nd year, and 25.0 for fish in their 3rd year. It is not known for 4th-year fish, but it is 24.0 for the 5th year, 18.6 - 20.4 for the 6th year, 18.0 - 19.3 for the 7th year, and 18.6 for the 8th year. The condition factor becomes lower as the age of the fish increases. Taking this change into consideration, an attempt was made to determine the range of length and size and the rate of growth for each age group. (Table 3). The presence or absence in the catch of length and weight groups corresponding to these ranges was used to check the accuracy of the determinations described above.

The black tuna landed at the Numazu fish market in 1936 comprised three groups, one very small one at 2.2 kan [18.2 lbs.], and the others at 1.0 kan [8.27 lbs.] and 0.4 kan [3.31 lbs.]. (Figure 2). Judging from the monthly changes in the situation, the 2.2 kan (8.2 kg) group are probably in their 3rd year, the 1.0 kan (3.75 kg) group are probably in their 2nd year, and the 0.4 kan (1.5 kg) group are probably fish of the year. At Numazu from April to June quite a few schools of 6th-year fish which have their modes at 22 kan (82 kg) and 5.3 shaku (161 cm) are fished. The black tuna landed at Numazu in the spring are mostly large fish, while fish of the year and 2nd-year fish predominate in the fall. Fish of the year are taken during approximately half of the year, but they account for 49% of the total catch. The 2nd-year fish which are taken throughout the year account for 47%, while the fish in their 3rd year which appear in small numbers in the spring comprise only 4%. Consequently it is thought that when black tuna enter their third year, they go out to pelagic waters and take up a migratory life.

The black tuna landed at Aburatsu in the spring of 1937 included fish of from 20 kan [165.4 lbs.] to over 80 kan [661.6 lbs.] in weight, but the major part of the catch was composed of groups having their modes at 34 kan [280.2 lbs.], 48 kan [397 lbs.], and 63 kan [521 lbs.]. (Table 5). According to length and weight data on the fish landed in May of that year, the average condition factor can be considered to be 19, and consequently the lengths of the three

Table 2 Results of Measurements of Black Tuna Vertebrae (by Aikawa and Katō)

Serial Number	Length (cm)	Weight (kg)	Ring No. 1		Ring No. 2		Ring No. 3		Ring No. 4		Ring No. 5		Total Radius	
			r_1	S.D.	r_2	S.D.	r_3	S.D.	r_4	S.D.	r_5	S.D.	T	S.D.
1	34.0	0.90	3.7	0.31									4.5	0.36
2	34.0	0.90	3.9	0.08									4.8	0.29
3	37.3	1.20	4.0	0.20									4.4	0.28
4	37.3	1.20	3.9	0.23									5.1	0.53
5	37.6	1.20	4.1	0.7									5.6	0.16
6	38.5	1.46	4.2	0.24									5.5	0.34
7	40.0	1.50	3.9	0.26									5.5	0.43
8	40.0	1.46	4.2	0.21									5.7	0.32
9	43.0	2.30	4.3	0.21									6.2	0.21
10	43.9	2.40	3.9	0.28									6.2	0.44
11	43.9	2.40	4.2	0.19									6.0	0.08
12	48.1	3.20	3.6	0.33	6.4	0.62							7.1	0.63
13	48.2	3.20	4.3	0.20	6.3	0.31							7.4	0.28
14	48.5	3.30	--	--	6.6	0.35							8.0	0.33
15	49.5	3.40	4.0	0.30	6.0	0.36							6.8	0.49
16	155.0	64.50	3.9	0.57	6.0	0.71	9.0	0.59	12.0	1.16	15.5	0.74	19.8	0.71
17	177.0	142.90	3.5	0.51	5.8	0.34	8.7	1.09	12.3	0.96	15.9	1.14	23.2	2.04
18	191.0	136.40	3.7	0.50	5.8	0.85	8.0	0.75	12.3	0.10	15.2	0.20	24.0	1.25
19	197.0	154.00	3.8	0.49	6.4	0.72	9.7	0.58	12.9	0.69	16.0	0.80	25.6	1.51
20	202.5	166.50	4.0	0.51	6.3	0.63	9.4	0.81	12.5	1.20	15.7	1.82	26.6	1.01
21	211.0	165.60	4.8	0.25	7.2	0.29	10.2	0.41	13.1	0.58	16.0	0.68	29.6	1.41
Average			4.05	0.32	6.4	0.52	9.4	0.68	12.6	0.88	15.8	0.96		

	Ring No. 6 r_6						Ring No. 7 r_7					Ring No. 8		Ring No. 8	
Number	17	18	19	20	21	average	18	19	20	21	average	21	average	21	average
ri	19.1	18.5	19.2	20.6	19.3	19.4	21.6	21.9	23.3	22.5	22.4	25.4	25.4	28.0	28.0
S.D.	1.63	0.50	1.13	0.90	0.75	1.10	0.95	1.44	0.88	1.01	1.15	1.11	1.11	1.43	1.43

Table 3 Age, length and weight range, rate of growth, and condition factor of black tuna

Age	Length	Weight	Growth Rate	Cond.Fact
Fish of the year (0 age group)	<43 cm	<2.3 kg	--	28
Second-year fish (I age group)	43 - 69	2.3 - 8.3	1.47	27
Third-year fish (II age group)	69 - 94	8.3 - 21.6	0.85	26
Fourth-year fish (III age group)	94 - 118	21.6 - 41.0	0.64	25
Fifth-year fish (IV age group)	118 - 145	41.0 - 73.0	0.58	24
Sixth-year fish (V age group)	145 - 168	73.0 - 110.0	0.41	23
Seventh-year fish (VI age group)	168 - 190	110.0 - 144.0	0.27	21
Eighth-year fish (VII age group)	190 - 210	144 - 185	0.25	20
Ninth-year fish (VIII age group)	210 - 230	185 - 230	0.22	20
Tenth-year fish (IX age group)	230 - 250	230 - 300	0.17	20

Table 4 Length, weight, and condition factor of black tuna

Length (m)	Weight (kg)	Condition Factor	Average C.F. by Age Groups
Numazu Market 1935 IV			
1.36	58.9	23.4	
1.39	57.4	21.7	fifth-year fish
1.42	76.9	26.9	24.0
1.45	79.5	26.1	
1.48	57.5	17.6	
1.51	78.5	22.8	
1.58	75.8	19.9	sixth-year fish
1.61	85.9	20.6	20.4
1.64	76.2	17.3	
1.67	84.3	18.2	
1.70	85.2	17.4	seventh-year fish
1.73	96.3	18.6	18.0
Aburatsu Market 1936 V			
1.70	90.0	18.3	
1.74	98.5	18.7	
1.76	107.0	19.7	sixth-year fish
1.78	105.0	18.6	18.6
1.82	112.5	18.7	
1.94	139.5	19.0	
2.04	161.0	19.3	seventh-year fish
2.08	168.8	19.6	19.3
2.14	173.2	18.8	
2.15	174.2	17.5	
2.15	195.0	19.6	
2.20	197.5	18.5	eighth-year fish
2.27	228.6	19.5	18.6
2.35	230.5	17.7	

weight groups are thought to have been respectively 187 cm, 210 cm, and 232 cm. Consequently these three groups probably belong to the classes of eighth-year, ninth-year, and tenth-year fish respectively. The fact that the modes of the weights and lengths are near the lower limits of the range for the respective age classes can probably be explained by the season at which the fish were taken. Eighth-year fish were 3%, ninth-year fish were 49%, and tenth-year fish were 20% of the total catch. The percentage of eighth-year fish does not vary greatly throughout the season, but the ninth-year fish are most numerous during the peak of the season, and the tenth-year fish are rather plentiful only at the beginning of the season.

Table 5 Weight groups of black tuna landed at Aburatsu from late January to May, 1937

Weight (kan) [8.27 lbs.]	Number of Fish	Weight (kan)	Number of Fish	Weight (kan)	Number of Fish
19	1	41	167	63	129
20	3	42	207	64	145
21	5	43	209	65	159
22	5	44	262	66	116
23	16	45	301	67	35
24	20	46	277	68	31
25	22	47	303	69	38
26	41	48	300	70	26
27	78	49	242	71	7
28	111	50	252	72	6
29	136	51	202	73	1
30	147	52	175	74	3
31	193	53	206	75	3
32	208	54	166	76	1
33	248	55	167	77	0
34	239	56	150	78	00
35	260	57	156	79	
36	246	58	162	80	
37	198	59	136	81	1
38	179	60	139	88	1
39	150	61	194		
40	158	62	151		

Kimura[2] sought to discover the rate of growth of the black tuna from the results of morphometric investigations of fish taken on the Omodera fishing ground in Shizuoka Prefecture. The size and weight ranges which he found for specimens in the age classes from fish of the year to fish in their fourth year agree in general with the author's results, but for age classes above the fourth year his results are greatly in error.

II. Yellowfin Neothunnus macropterus (Temminck & Schlegel)

In June of 1937 four small yellowfin landed at the Numazu market and two large yellowfin purchased at the Tōkyō market were obtained, and age determinations were made. The yellowfin has 38 vertebrae, of which the five from No. 5

(2) Kimura, Kinosuke; Bull. Jap. Soc. Scientific Fisheries 1(1), 1932.

Table 6 Results of the measurements of the vertebrae of yellowfin tuna (measured by Katō)

No.	Length (cm)	Weight (kg)	Ring r_1	No.1 S.D.	Ring r_2	No.2 S.D.	Ring r_3	No.3 S.D.	Ring r_4	No.4 S.D.	Ring r_5	No.5 S.D.	Total T	Radius S.D.
1	41.4	1.6	5.0	0.07									5.9	0.20
2	51.0	3.1	5.9	0.19									7.1	0.19
3	61.8	5.0	5.6	0.22	7.5	0.21							8.7	0.36
4	77.0	10.0	5.9	0.21	7.6	0.27	9.2	0.33					10.9	0.45
5	96.0	24.4	5.7	0.25	7.6	0.35	9.3	0.47	11.0	0.36			12.9	0.53
6	120.0	43.1	5.6	0.21	7.7	0.41	9.8	0.42	11.7	0.44	13.6	0.42	15.2	0.30
Average annual rings			5.6	0.20	7.6	0.32	9.4	0.41	11.4	0.40	13.6	0.42		

to No. 10 were used. The method of measuring was the same as for the black tuna. (Table 6).

In some cases what appear to be annual rings having radii of over 3.7 mm can be observed, but it is thought that these result from irregularities in the structure of the central portion. Where the variation of the radius in comparison with other annual rings is very marked, the line cannot be considered an annual ring. Accordingly those of 5.6±0.20 mm were taken as the first ring (r_1). The correlation between the total radius of the centrum (T mm) and the length of the fish (L cm) is shown by $L_1/L_2 = (T_1 - 1)(T_2 - 1)$. From the radius r_n mm of annual ring No. n, the length (L_n cm) at which the ring was completed can be found by the following formula:

$$L_n = 8.4\, r_n - 8.4$$

Table 7 shows the range of lengths for each age. The results of measurements taken on small yellowfin landed at Numazu market from June to August 1936 show (Table 8) that the condition factor for yellowfin tuna varies between 20 and 30, and that it decreases as the fish grows older. Taking this change into consideration, the weight range for fish of each age group was estimated. The weight of fish of the year and second-year fish is thought to be somewhat greater than these calculations indicate. The rate of growth of the yellowfin is much lower than that of the black tuna. Kimura (op.cit.) attempted to determine the growth rate of yellowfin from morphometric data collected at Omodera, and for fish up to their third year his results are in general agreement with those obtained by the author, but for older fish, just as in the case of the black tuna, he is greatly in error.

Yellowfin landed at the Numazu market from May to August of 1936 comprised weight groups having their modes at 1.2 kan [9.9 lbs], 2.4 kan [19.9 lbs.], 4 kan [33.1 lbs.], 6 kan [49.6 lbs.], 8 kan [66.2 lbs.], and 12 kan [99.2 lbs.]. The catch from September to December contained three groups having their modes at 0.5 kan [4.1 lbs.], 1.2 kan [9.9 lbs.], and 2.0 kan [16.5 lbs]. The 0.5 kan group are clearly fish of the year and the others belong to age classes from the second to the seventh year. Weight groups are seen which agree with the weight ranges given for the various year classes in Table 7. In the spring catches the 2 kan and 6 kan groups do not show up very clearly, but their existence is undeniable.

Table 7 Age, length and weight range, growth rate, and condition factor of yellowfin

Age	Length	Weight	Growth Rate	Cond. Factor
Fish of the year (0 age group)	<38 cm	<1.50 kg		27.0
Second-year fish (I age group)	38-54	1.50-4.3	1.05	27.0
Third-year fish (II age group)	54-70	4.3 -8.6	0.70	25.0
Fourth-year fish (III age group)	70-85	8.6-14.0	0.49	23.0
Fifth-year fish (IV age group)	85-100	14.0-21.4	0.43	21.5
Sixth-year fish (V age group)	100-115	21.4-34.0	0.37	20.0
Seventh-year fish (VI age group)	115-130	34.0-44.0	0.30	20.0
Eighth-year fish (VII age group)	130-145	44.0-57.5	0.27	20.0
Ninth-year fish (VIII age group)	145-160	57.5-75.0	0.24	20.0

Table 8 Morphometric data on yellowfin landed at Numazu market May-December, 1936

Length (cm)	Weight (kg)	Condition Factor	Length (cm)	Weight (kg)	Condition Factor
33.4	0.98	26.6	93.9	17.9	21.6
36.4	1.40	29.0	96.9	18.9	20.7
39.4	1.69	27.6	100.0	21.4	21.4
42.4	1.95	25.6	103.0	20.5	18.8
45.4	2.70	28.8	106.0	22.3	18.7
48.4	3.05	26.8	109.0	27.8	21.4
51.5	3.89	27.5	112.1	27.1	19.3
54.5	4.45	26.7	115.1	26.4	17.4
57.6	4.91	25.2	118.1	30.6	18.6
60.6	5.83	25.7	121.2	33.9	19.2
63.6	6.58	25.1	124.2	37.2	19.5
66.6	7.44	24.8	127.2	40.1	19.6
69.6	8.36	24.4	130.3	44.0	20.0
72.7	8.82	20.5	133.3	45.4	19.3
75.7	10.6	24.6	136.3	50.3	20.0
78.7	10.6	21.5	139.4	53.4	19.8
81.8	13.3	24.2	142.4	54.9	19.1
84.8	14.9	24.4	145.4	60.1	19.4
87.8	15.5	22.8	148.5	71.2	21.5
90.9	15.9	21.1	151.5	70.5	20.1

In the Numazu landings for 1937 also weight groups can be seen which correspond to each year class. (Table 9).

The small yellowfin stay in the waters near Numazu for a longer period of time than do the small black tuna and fish up to the third-year class are taken the year round. Probably fourth-year and older fish go out into pelagic waters and take up a migratory life. Just as in the case of the black tuna, large fish of the fourth year and older are most numerous in the spring and do not appear in the autumn.

III. Albacore Germo germo (Lacépède)

Ten large albacore taken by the Fuji Maru of the Shizuoka Prefectural Fisheries Experiment Station near Midway I. in January 1938, and five small fish taken on trolling lines by the same Station's Sōyō Maru off northeastern Japan were obtained and age determinations by means of the vertebrae were made. (Table 10). Of the 38 vertebrae which albacore in most cases posses, the five from No. 9 to No. 14 were taken and the total radius of the centrum (T mm) and the radius of each ring (r mm) were measured. (Table 11).

The correlation between body length (L cm) and total radius (T mm) is shown by $L_1/L^3_2 = (T_1 - 7.9)/(T_2 - 7.9)$. (Figure 6).

From the radius (r_n mm) of annual ring No. n, the length (L_n cm) at which the ring was completed can be found by means of the formula $L_n = 5.8\ r_n + 17.5$. (Table 12). For the albacore taken by the Fuji Maru in the waters east of Cape Nojima (28° - 34° N, 170° - 173° E) in the spring of 1937 the average condition

Table 9 Length groups of yellowfin tuna landed at Numazu market in 1937

Weight kan	Number of Fish			Weight kan	Number of Fish	
	May, June, July	August, Sept.	Nov., Dec.		May, June, July	August, Sept.
0.2		2		5.0	69	2
0.3		24	3	5.2	45	4
0.4		132	59	5.4	44	4
0.5		78	236	5.6	17	4
0.6		36	153	5.8	18	3
0.7	2	21	63	6.0	9	3
0.8	2	7	31	6.2	7	5
0.9	7	9	10	6.4	8	1
1.0	11	15	10	6.6	2	1
1.1	7	16	16	6.8	1	1
1.2	15	13	14	7.0	--	5
1.3	4	3	12	7.5	--	3
1.4	7	6	4	8.0	3	4
1.5	4	--	5	8.5	5	6
1.6	4	2		9.0	3	3
1.7	2	2		9.5	3	3
1.8	8	3		10.0	1	2
1.9	10	8		10.5	3	--
2.0	6	3		11.0	3	--
2.2	22	6		11.5	6	3
2.4	22	3		12.0	2	--
2.6	23	8		12.5	4	3
2.8	17	3		13.0	7	3
3.0	25	--		13.5	3	5
3.2	22	1		14.0	3	--
3.4	24	1		14.5	3	6
3.6	73	9		15.0	2	9
3.8	124	3		15.5	--	3
4.0	161	17		16.0	2	4
4.2	143	5		16.5	1	2
4.4	121	6		17.0	--	--
4.6	102	9		17.5	--	2
4.8	97	4		18.0	2	1

Table 10 Morphometric data on albacore

No.	1	2	3	4	5	6	7	8	9	10
Total length	89.0	91.5	96.0	105.0	106.0	106.5	108.0	113.5	123.0	125.0
Body length (L)	76.5	79.0	82.5	89.0	91.0	92.0	96.0	99.5	104.0	106.0
Head length	23.0	25.0	23.5	27.0	28.0	29.0	29.0	30.0	32.0	31.5
1st dorsal rays	14	14	14	13	14	14	14	14	14	14
2nd dorsal rays	14	14	14	14	14	14	14	14	14	14
Anal rays	14	13	14	--	14	14	14	14	14	14
Pectoral length	34.0	38.0	41.5	42.0	41.0	44.0	45.0	43.5	47.0	49.0
Vertebral count	38	39	38	38	38	38	38	38	38	38
Weight	8.75	11.2	13.5	10.5	10.9	14.2	15.5	23.5	26.4	25.0
Condition factor	19.5	22.7	23.7	14.9	14.5	18.2	17.5	23.6	23.4	21.0

factor was 24 (Table 13). From this the length and weight ranges and growth rates for each age group can be found. (Table 12).

Uno [1,2] found that of the three groups comprised in the catch of albacore from the waters east of Cape Nojima, those having an average length of 79.15 ± 1.30 cm were fifth-year fish (IV age group), those averaging 79.15±3.68 cm were sixth-year fish (V age group), and those averaging 89.55±2.25 cm were seventh-year fish (VI age group). From the results of his second survey[2] he found that the fifth-year fish averaged 69.04±1.98, the sixth-year fish 81.56±3.82, and the seventh-year fish 89.70±1.98 cm. The average lengths correspond to the length ranges which the author has established for fifth-year to seventh-year fish. The albacore differ from the black tuna and the yellowfin in that the weights of the middle-aged fish show the highest values in the range.

In the fish taken from these same waters (28° - 34° N, 170° - 173° E) from January to May of 1937 length groups could be detected which had their modes at 25 cm, 45 cm, 56 cm, 62 cm, 74 cm, and 83 cm (Figure 7 lower). These correspond respectively to age classes from fish of the year to sixth-year fish. There is another group between 90-100 cm which is thought to consist of seventh-year fish, but the mode is not clear. In the catch for 1936 (Figure 7 upper) there are weight groups having their modes at 0.6 kan, 1.6 kan, 2.7 kan, and 3.7 kan, and they are thought to belong to the second-year and fourth- to sixth-year classes.

Thus the length and weight groups found in the catch correspond with the length and weight ranges established by means of the vertebrae and more or less guarantee the correctness of the determinations.

Technician Shitoku Era of the Shizuoka Prefectural Fisheries Experiment Station has been able to make a good-quality canned product from albacore of over 2.5 kan in weight, but fish under that weight are not suitable. This means that fish in their sixth-year and older are best suited for canning.

IV. Skipjack Katsuwonus vagans (Lesson)

Twenty skipjack taken off Palao August 4, 1937 were received from Dr. Shōkichi Yamamoto. Age determinations were made on these fish along with other specimens from the Northeastern area.

Measurements were made of the annual rings in the first five vertebrae of the skipjack. (Table 14). The correlation between the total radius (T mm) of the centrum and the body length (L cm) is shown by the formula $L_1/L_2 = (T_1 + 0.53)/(T_2 + 0.53)$. (Figure 8). The body length (L cm) at which Ring No. n was completed can be found from the radius (r_n mm) by the following formula.

$$L_n = 7.1\, r_n + 4$$

Aikawa[3] made age determinations on 20 skipjack from Zunan Is. waters and got a correlation between total radius of centrum (T mm) and body length (L cm) of $L_1/L_2 = (T_1 + 1.54)/(T_2 + 1.54)$, and for finding from the radius of ring n the length at which the ring was completed he used the formula

$$L_n = 6.2 r_n + 5.5$$

(1) Uno, Michio; Bull. Jap. Soc. Sci. Fish. 4(5), 1936
(2) Uno, Michio; Bull. Jap. Soc. Sci. Fish. 5(4), 1936
(3) Aikawa, Hiroaki; Bull. Jap. Soc. Sci. Fish. 6(1), 1937

Table 11 Results of measurements of albacore vertebrae (Aikawa)

No.	Length (L cm)	Total T mm	Radius S.D.	Ring No.1 $r_1$mm	S.D.	Ring No.2 $r_2$mm	S.D.	Ring No.3 $r_3$mm	S.D.	Ring No.4 $r_4$mm	S.D.	Ring No.5 r5mm	S.D.	Ring No.6 $r_6$mm	S.D.
1	57.0	6.5	.37	3.0	.37	5.1	.49								
2	57.0	7.0	.41	3.1	.21	5.0	.28								
3	65.0	7.0	.17	3.2	.36	5.0	.25	6.4	.21						
4	69.0	7.2	.45	3.0	.17	4.0	.26	5.6	.35						
5	72.0	9.8	.33	3.3	.28	5.2	.28	6.8	.25						
6	76.5	10.4	.12	3.6	.21	4.9	.55	6.3	.55	8.4	.82	9.3	.38	10.4	.23
7	79.0	10.8	.53	--	--	4.8	.57	6.2	.57	7.7	.37	9.2	.30	11.0	.12
8	82.5	11.0	.28	3.3	.39	4.9	.25	6.7	.30	8.3	.50	9.9	.49	10.8	.28
9	89.0	12.6	.59	--	--	--	--	5.6	.46	7.2	.41	9.0	.53	11.3	.45
10	91.0	12.1	.66	--	--	--	--	6.6	.28	7.8	.29	9.5	.43	11.2	.54
11	92.0	13.0	.58	--	--	5.2	.16	6.4	.54	7.7	.59	9.4	.54	11.4	.42
12	96.0	12.7	.27	3.0	.09	4.8	.29	6.4	.35	7.8	.50	9.6	.52	11.0	.58
13	99.5	13.9	.68	--	--	--	--	6.5	.43	7.8	.54	9.3	.45	11.1	.52
14	104.0	15.0	.58	--	--	--	--	6.6	.31	8.2	.79	9.6	.50	11.3	.52
15	106.0	15.0	.40	--	--	4.3	.30	6.1	.65	7.7	.54	9.1	.58	10.8	.61
Average of rings				3.2	.28	4.9	.36	6.4	.43	7.9	.56	9.4	.48	11.0	.46

Ring No. 7					Ring No. 8			
No.	13	14	15	average	No.	14	15	average
$r_7$mm	12.8	12.8	12.6	12.7	rgmm	14.2	14.2	14.2
S.D.	.42	.67	.40	.51	S.D.	.59	.72	.66

Table 12 Length, weight, and age of albacore

Age	Length	Weight	Growth Rate
Fish of the year (0 age group)	< 35 cm	< 1.0 kg	
Second-year fish (I age group)	34-46	1.0-2.3	0.84
Third-year fish (II age group)	46-55	2.3-4.0	0.55
Fourth-year fish (III age group)	55-64	4.0-6.3	0.46
Fifth-year fish (IV age group)	64-73	6.3-9.2	0.40
Sixth-year fish (V age group)	73-82	9.2-13.2	0.36
Seventh-year fish (VI age group)	82-91	13.2-18.1	0.34
Eighth-year fish (VII age group)	91-100	18.1-24.0	0.29
Ninth-year fish (VIII age group)	>100	> 24.0	?

Table 13 Morphometric data on albacore taken east of Cape Nojima, Jan.-May 1937 (Fuji Maru survey)

Condition Factor	Weight (kg)	Number of Fish	Length (cm)	Condition Factor	Weight (kg)	Number of Fish	Length (cm)
24.3	1.69	1	42	24.3	7.3	7	67
23.9	1.88	2	43	23.9	7.5	6	68
23.5	1.96	3	44	23.7	7.8	14	69
23.0	2.08	3	45	24.2	8.3	16	70
23.1	2.25	1	46	23.2	8.5	9	71
22.7	2.44	2	47	22.8	8.5	23	72
22.6	2.59	1	48	23.6	9.2	15	73
24.0	3.00	1	50	23.7	9.6	26	74
26.1	5.10	1	58	23.7	10.0	22	75
23.6	4.8	5	59	23.0	10.1	14	76
24.1	5.2	9	60	23.2	10.6	18	77
24.7	5.6	12	61	23.8	11.3	16	78
23.5	5.6	16	62	23.0	11.3	11	79
24.0	6.0	4	63	23.2	11.9	11	80
24.0	6.3	7	64	22.4	11.9	8	81
23.7	6.5	7	65	22.5	12.4	6	82
24.3	7.0	5	66	21.6	12.3	10	83

Accordingly it appears that there is a difference between Zunan and Palao skipjack in regard to the correlation between body length and growth of the vertebrae. From the data from the Palaos it is surmised that the first ring (r_1) is completed at a body length of 27 cm, the second (r_2) at 37 cm, the third (r_3) at 46.5 cm, and the fourth (r_4) at 55 cm. For the Zunan specimens the corresponding figures are 26 cm, 34 cm, 43 cm, and 54 cm. This means that if one takes errors in measuring into consideration, the body lengths at which the various rings are formed can be considered equal for both groups of fish. The development of the vertebrae in the Zunan schools is poor by comparison with that of the Palao schools.

Taking the average condition factor for Palao skipjack as 25 (Table 15), the length and weight ranges and rate of growth for each age were determined. (Table 16). With skipjack from Japanese waters the author classed those having a condition factor under 20 as shoal fish and those with a condition factor of over 20 as fish from migratory schools. The fish taken in Palao waters had an average condition factor of 25.3 and so were considered to be migratory fish, while those from Zunan waters, with an average of 20, were close to the shoal schools. It is thought that the fish in these two categories set up by the author also show a difference in the rate of growth of the vertebrae. The author wishes to verify this point by a consideration of more data in the future.

Table 14 Results of vertebral measurements on Palao skipjack (measured by Aikawa)

No.	Length (L cm)	Total T mm	Radius S.D.	Ring No. 1 r_1 mm	S.D.	Ring No. 2 r_2 mm	S.D.	Ring No. 3 r_3 mm	S.D.	Ring No. 4 r_4 mm	S.D.	Ring No. 5 r_5 mm	S.D.	Ring No. 6 r_6 mm	S.D.
1	32.5	3.9	.23	2.6	.23										
2	38.0	5.2	.14	3.3	.31	4.4	.44								
3	39.0	5.1	.55	2.9	.42	4.6	.46								
4	39.0	5.4	.39	3.4	.32	4.4	.49								
5	41.0	5.1	.38	3.2	.26	4.3	.37								
6	41.0	5.2	.24	3.2	.19	4.3	.26								
7	42.5	5.4	.60	3.1	.45	4.4	.46								
8	43.0	5.3	.48	2.9	.07	4.2	.53								
9	43.5	5.4	.46	3.1	.45	4.4	.46								
10	44.0	5.7	.38	3.3	.28	4.7	.29								
11	44.5	5.3	.31	3.3	.28	4.4	.30								
12	50.5	7.0	.72	3.3	.34	4.4	.42	5.7	.29						
13	51.0	6.2	.14	3.2	.20	4.2	.22	4.9	.54						
14	51.0	7.0	.71	3.3	.40	4.5	.33	5.7	.55						
15	51.5	6.6	.36	3.1	.08	4.2	.15	5.5	.32						
16	52.5	6.5	.47	3.2	.32	4.4	.34	5.6	.52						
17	53.0	6.6	.41	3.7	.26	4.6	.31	5.6	.34						
18	54.0	7.3	.77	3.5	.42	4.6	.34	5.5	.36	7.7	.77				
19	54.5	7.2	.47	3.5	.44	4.4	.54	5.6	.40	6.4	.63				
20	63.5	7.8	.54	3.5	.32	4.7	.35	6.0	.49	7.2	.49				
Palao fish average				3.2	.32	4.5	.38	5.7	.43	7.2	.64				
Zunan fish average				2.6		3.9		5.4		7.2					
21	50.0	6.5	.50	3.3	.32	4.6	.69	5.7	.52						
22	60.5	8.2	.57	3.9	.48	5.0	.55	6.4	.80	6.9	.64				
23	77.0	10.2	.49	3.4	.27	4.6	.47	6.1	.44	7.2	.36	8.2	.42	9.3	.42
24	78.5	10.5	.83	3.2	.18	4.3	.28	6.3	.45	7.5	.51	8.5	.69	9.7	.88
Average for annual rings				3.4	.33	4.5	.57	6.0	.57	7.2	.52	8.5	.57	9.6	.64
Overall average				3.2	.32	4.5	.43	5.8	.48	7.2	.58	8.5	.57	9.6	.64

Table 15 Morphometric data on skipjack

No.	Length	Weight	C. F.	No.	Length	Weight	C. F.	No.	Length	Weight	C. F.
1	32.5cm	0.80kg	23.5	9	43.5	1.96	23.8	17	53.0	3.98	26.7
2	38.0	1.28	23.3	10	44.0	2.20	25.8	18	54.0	3.98	25.3
3	39.0	1.38	23.3	11	44.5	2.12	24.1	19	54.5	4.64	28.7
4	39.0	1.41	23.8	12	50.5	3.43	26.6	20	63.5	7.03	27.5
5	41.0	1.61	23.3	13	51.0	3.36	25.3	21	50.0	2.66	21.3
6	41.0	1.74	25.2	14	51.0	3.61	27.2	22	60.5	5.25	23.7
7	42.5	1.90	24.8	15	51.5	3.69	27.0	23	77.0	9.00	19.7
8	43.0	1.95	24.5	16	52.5	3.68	25.4	24	78.5	14.00	33.6

Fishing ground and time catch was made - Nos. 1 - 20 were taken at Palao August 4, 1937. No. 21 was bought at the market Feb. 26, 1937. No. 22, 34-43, 144-22 Feb. 7, 1937. No. 23 was bought at the market Feb. 26, 1937. No. 24, 28-30, 154-00 Jan. 13, 1937. [TN. The figures after Nos. 22 and 24 probably represent the positions at which the fish were taken.]

Table 16 Age, length and weight range, and rate of growth for skipjack

Age	Length	Weight	Growth Rate
Fish of the Year (0 age group)	< 27 cm	< 0.4 kg	
Second-year fish (I age group)	27-37	0.4-1.3	0.90
Third-year fish (II age group)	37-46	1.3-2.5	0.69
Fourth-year fish (III age group)	46-55	2.5-4.1	0.53
Fifth-year fish (IV age group)	55-64	4.1-6.5	0.46
Sixth-year fish (V age group)	64-72	6.5-9.5	0.37
Seventh-year fish (VI age group)	72-80	9.5-13.0	0.31
Eighth-year fish (VII age group)	> 80	>13.0	?

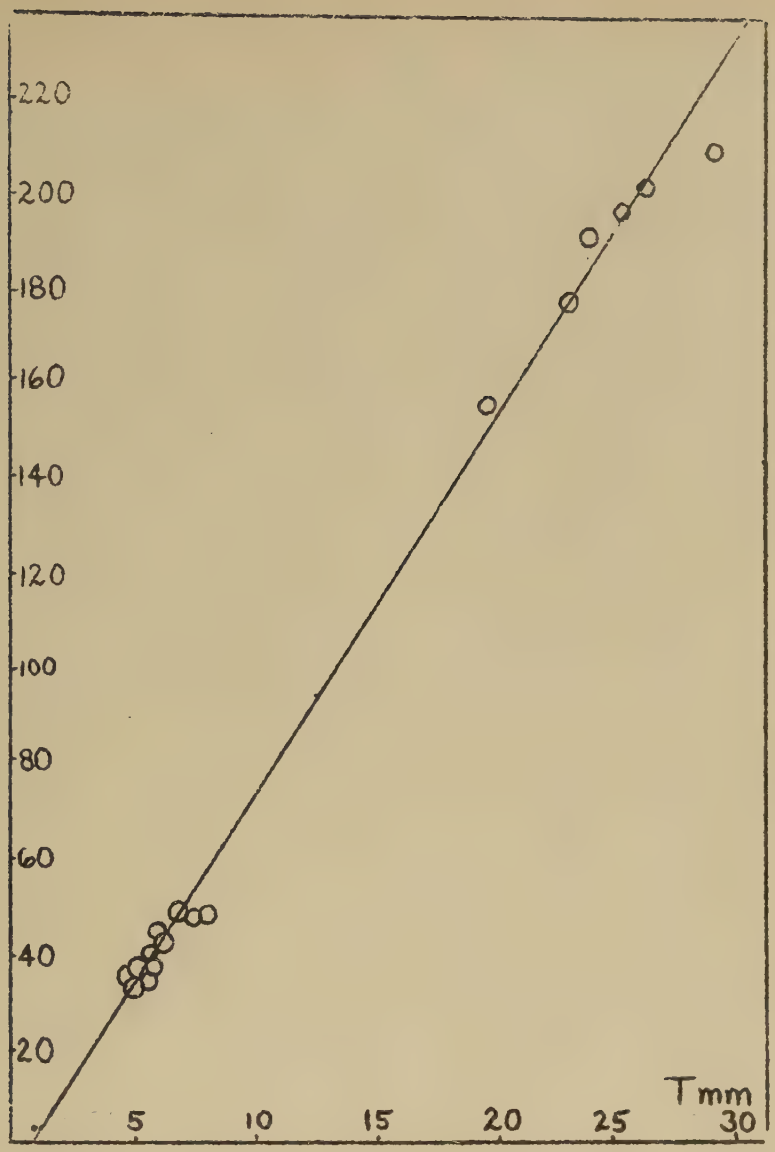

Figure 1 Correlation between body length (L cm) and total radius of centrum (T mm) in black tuna

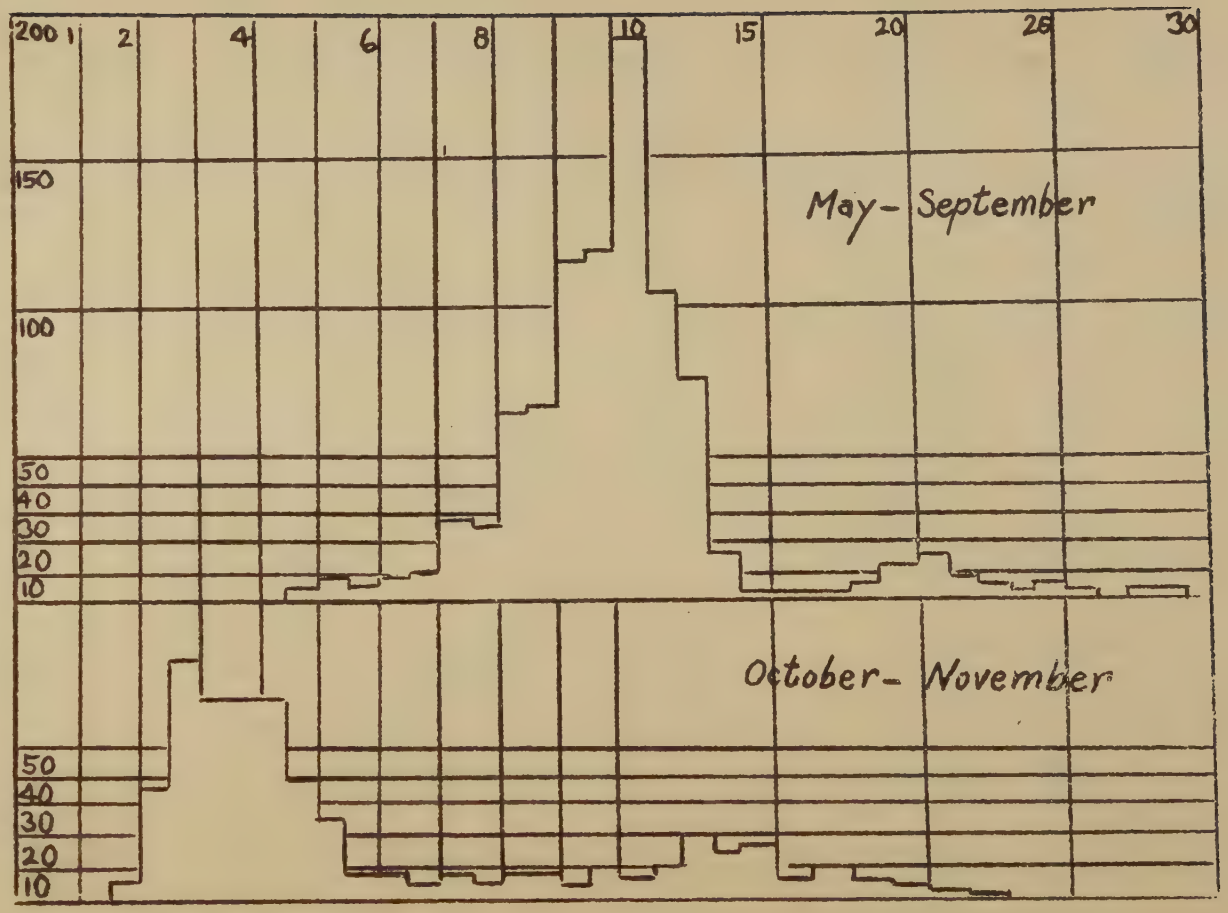

Figure 2 Weight groups of small black tuna landed at Numazu in 1936

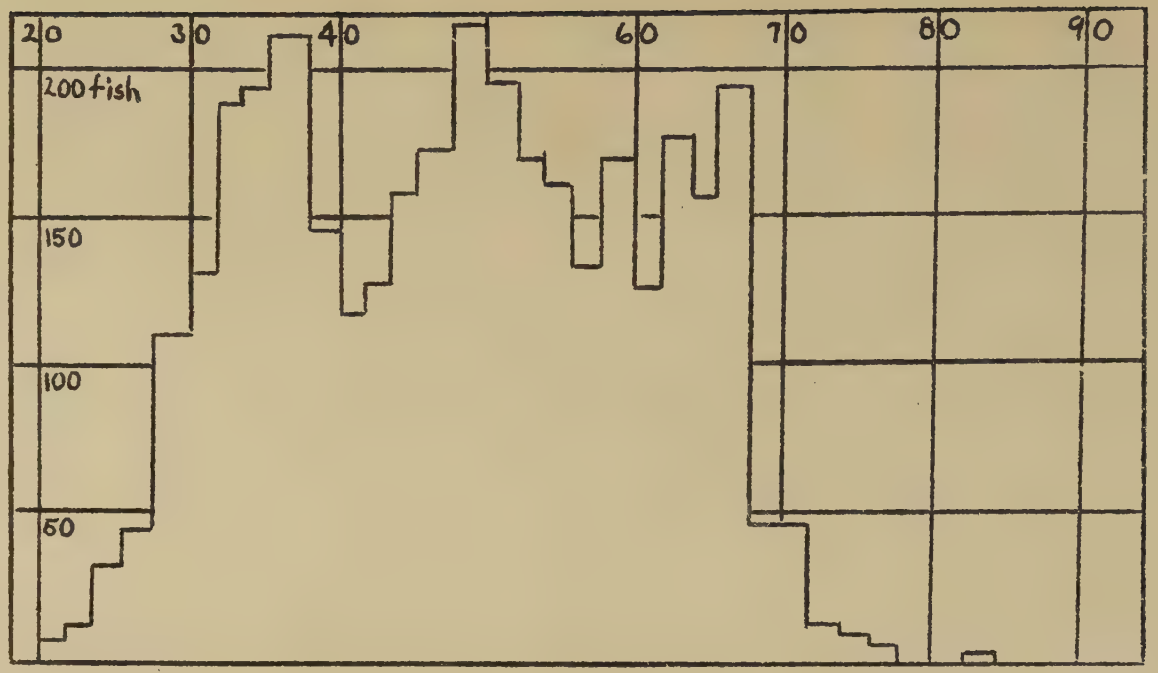

Figure 3 Weight groups of black tuna landed at Aburatsu in March 1937

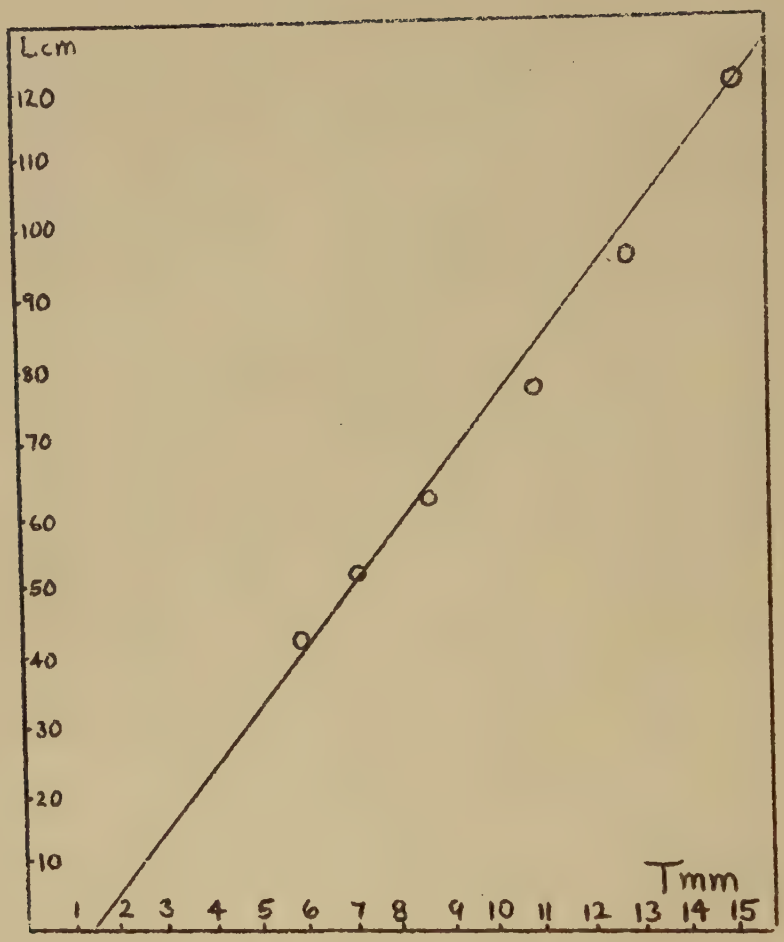

Figure 4 Correlation between body length (L cm) and total radius of centrum (T mm) in yellowfin tuna

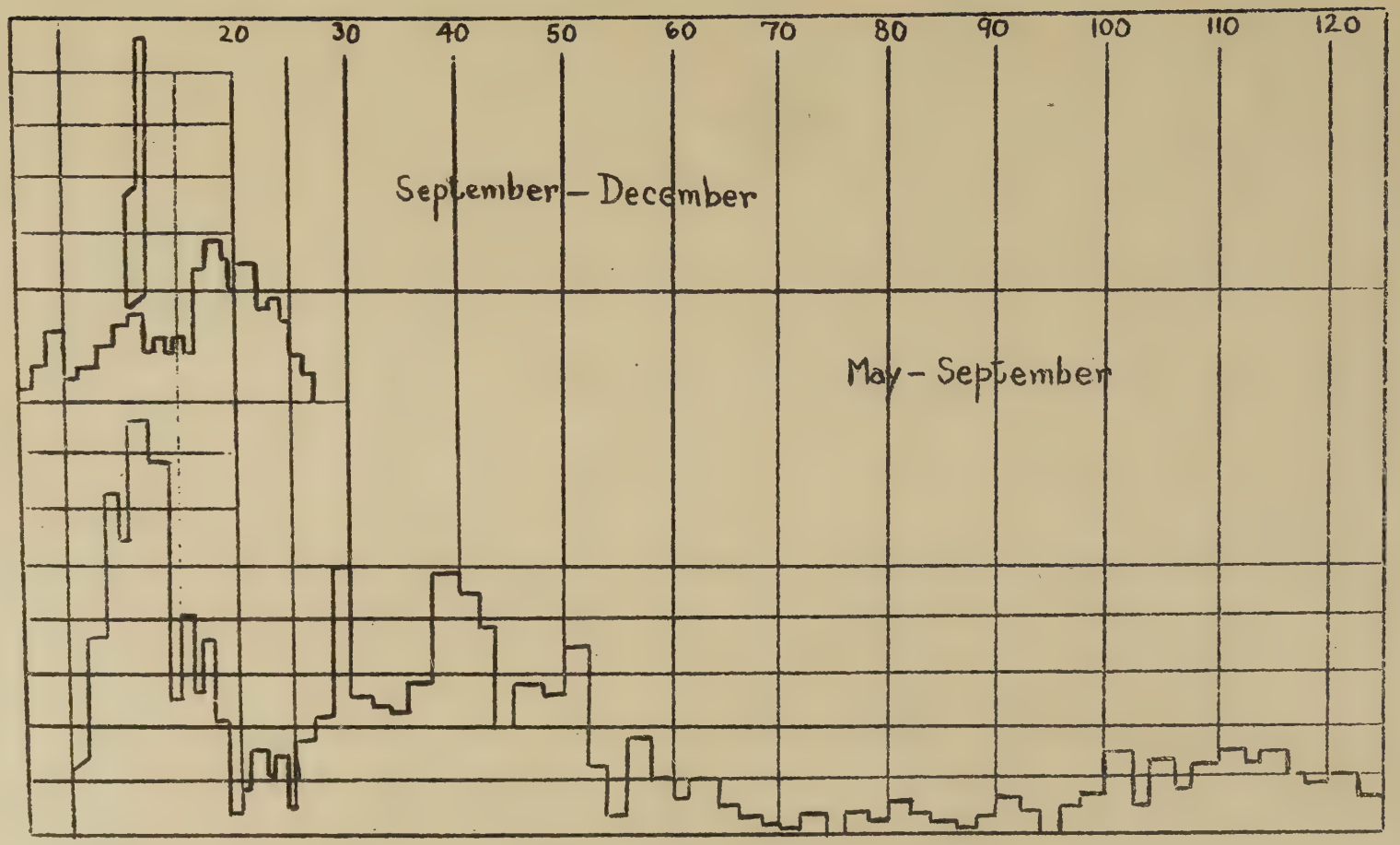

Figure 5 Weight groups of yellowfin landed at Numazu
[The figures on the vertical axis are illegible.]

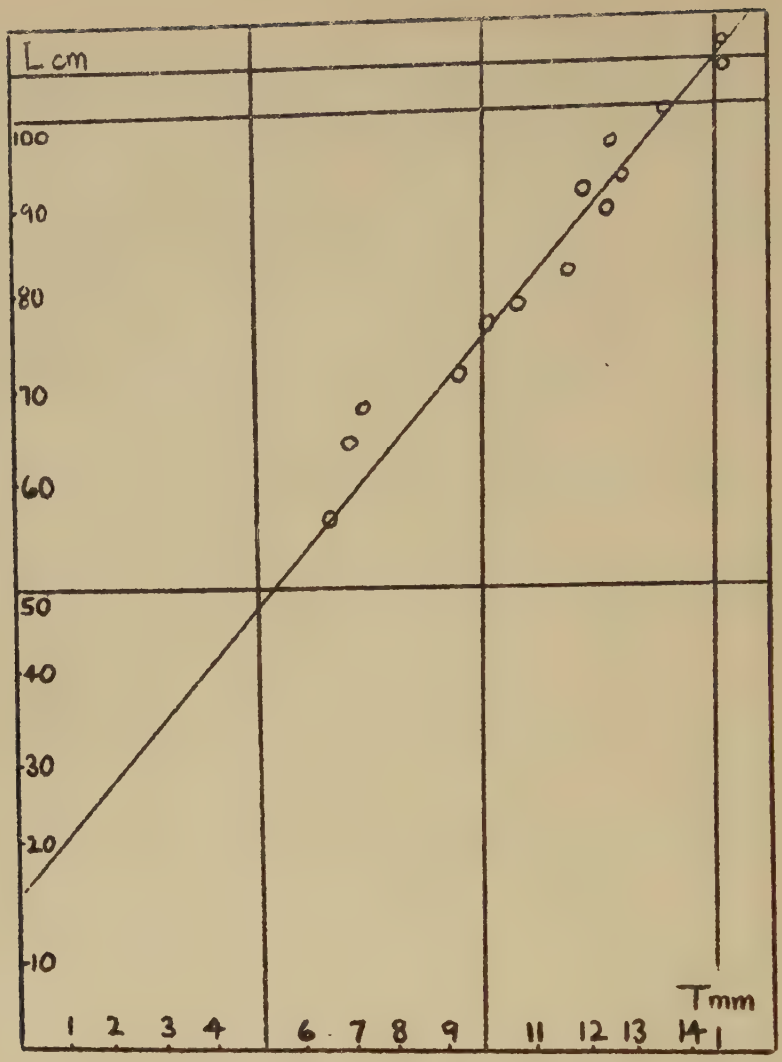

Figure 6 Correlation between body length (L cm) and total radius of centrum (T mm) in the albacore

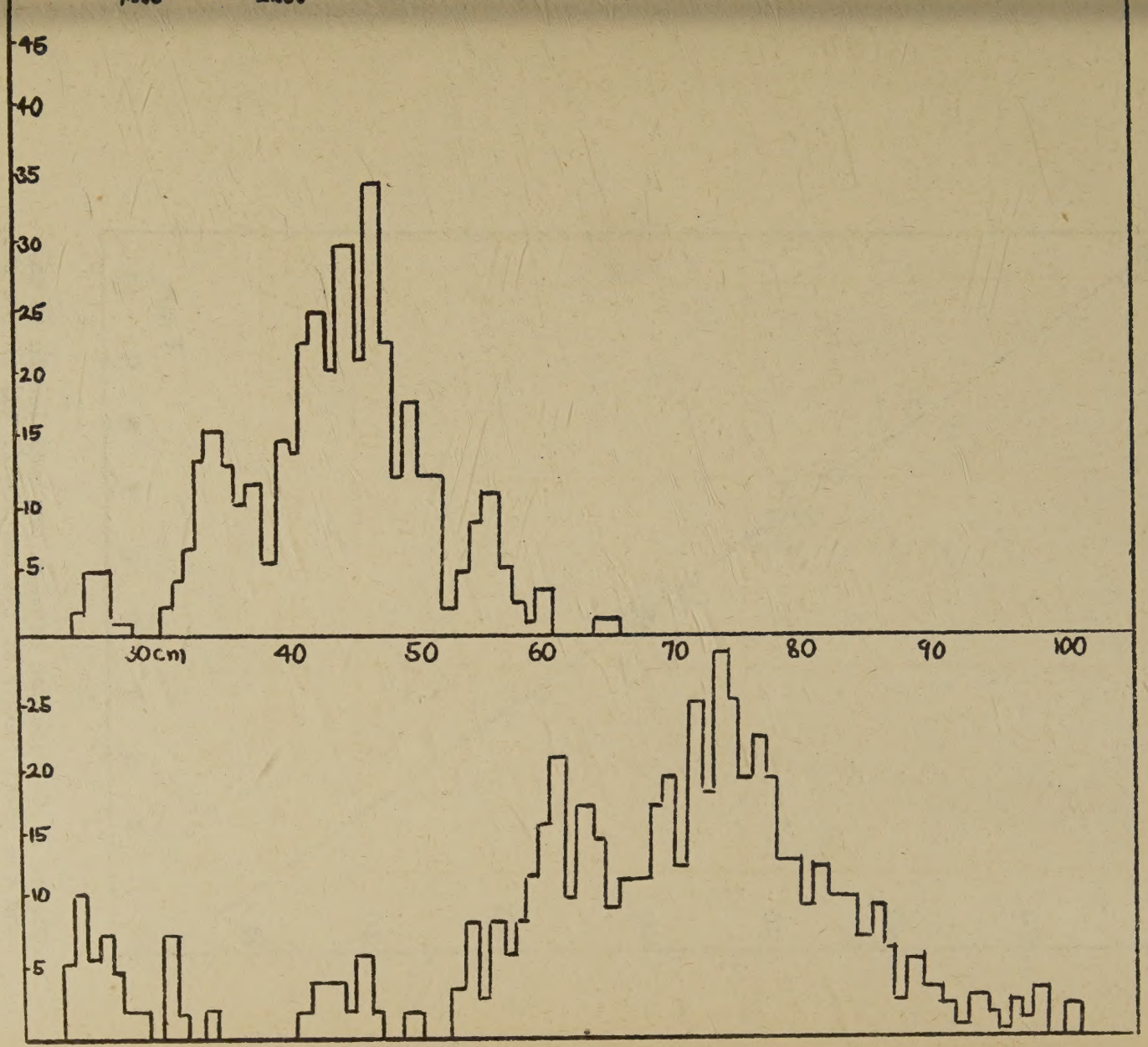

Figure 7. Weight and length groups of albacore taken by the Fuji Maru.
(Upper) Jan.-May 1936; horizontal axis = weight in kan [8.27 lbs.], vertical axis = number of fish; (lower) Jan.-May 1937; horizontal axis = length, vertical axis = number of fish

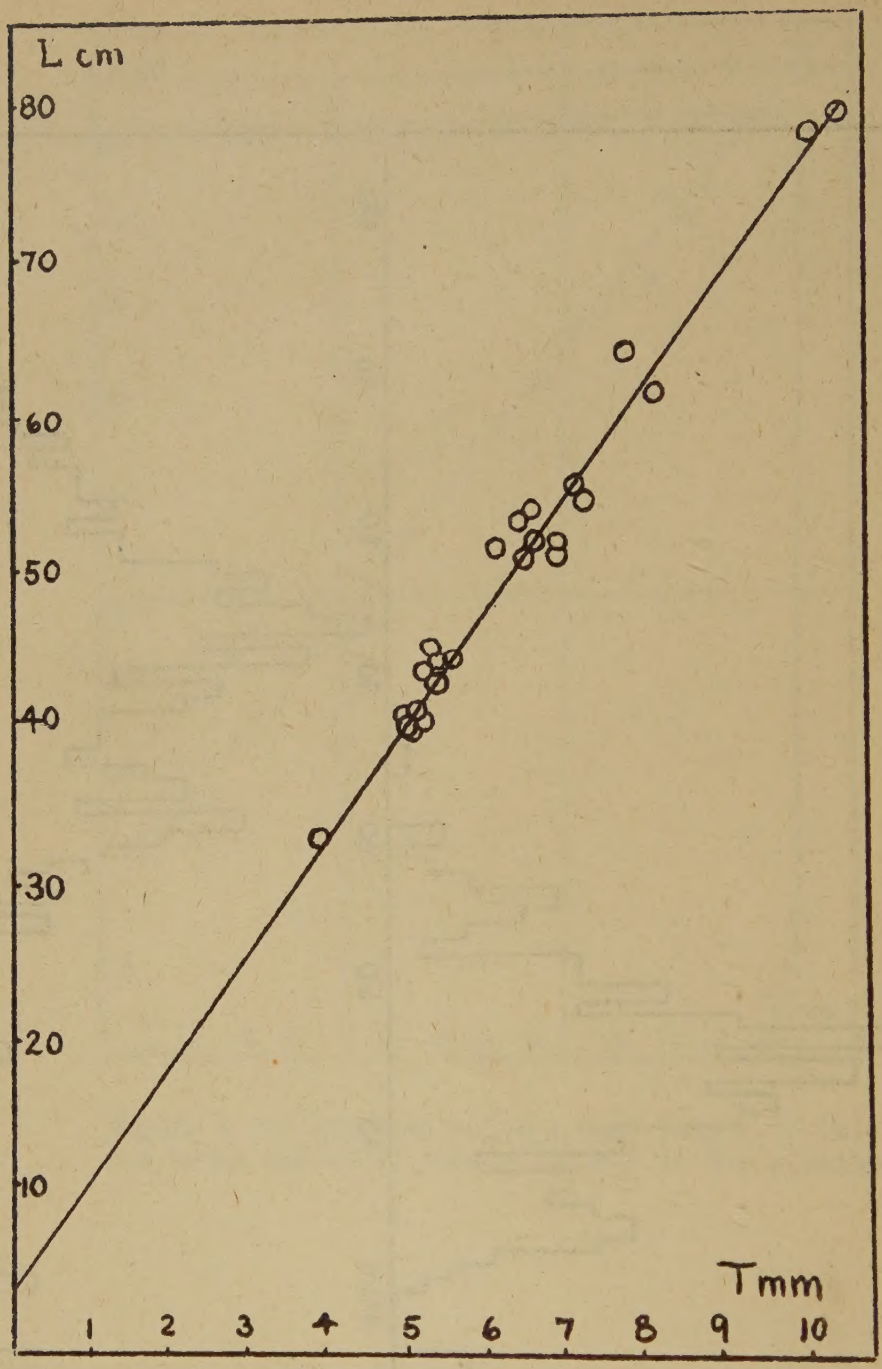

Figure 8 Correlation between the body length (L cm) and the total radius of the centrum (T mm) in the skipjack

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